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Roadmap to attain 100 MV/m gradients and 100 MeV total energy gain in wakefield acceleration using the current AWA facility

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Introduction

The planned upgrade of the AWA (Argonne Wakefield Accelerator) RF photocathode gun is well underway. When completed, it will capable of generating 32 – 64 pulses in a train with 10 – 50 nC/pulse. The beam energy will increase to 18 MeV. This new RF photocathode gun is under construction and expected to be in operation by summer 2000.

In this note, we present a proposed experiment using the existing components of the AWA facility (with the upgraded RF gun) which makes use of the step-up transformer structure which we constructed and demonstrated at lower accelerating gradients. The goal is to achieve with the new experiment using a wakefield transformer structure:

1. 100 MV/m gradient in stage II
2. witness beam accelerated to 100 MeV.

Approaches

As discussed in WF-183 (http://www.hep.anl.gov/awa/awa/docs/wf183.pdf), the new gun can produce up to 64 pulses with 1 RF period (770 ps) separation between the pulses. We will use this beam to drive the stage I tube already fabricated and tested using the present AWA beams

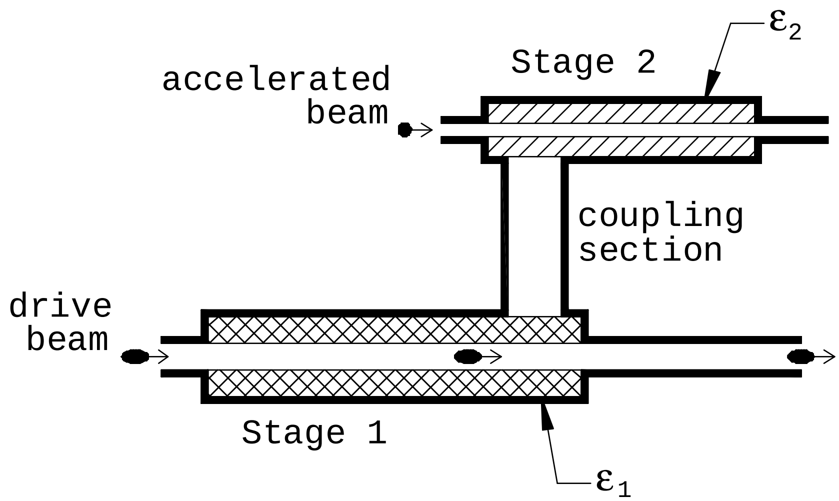

Figure 1. Schematic diagram of the step-up transformer for this proposed experiment.

The transformer structures to be used in these demonstrations have the following parameters:

Structure I (7.8 GHz)

- Drive beam: 50 nC, 64 pulses (1 RF period separation between the pulses) giving a total RF pulse length of 50 ns.
- Stage I: · Dielectric: Corderite, a_1 = 6.00 mm, b_1 = 11.15 mm, ε_1 = 4.6
    - Wakefield amplitude E_z = 45 MV/m. Stage I length L_1 = 23.0 cm, RF power generated = 500 MW (Flat top).
- Stage II: Dielectric: E20, a_2 = 3.00 mm, b_2 = 5.41 mm, ε_2 = 20
    - Wakefield E_{z2} = 112 MV/m. Stage II length L_2 = 85 cm. Net acceleration = 95 MeV.

Structure II (15.6 GHz)

- Stage I
    - Q= 20 nC $\times$ 64 pulses.
    - Dielectric: Corderite, a_1=5 mm, b_1=7.22 mm, ε_1 = 4.6
    - Wakefield E_{z1} = 44 MV/m
    - Stage I length L_1 = 23.0 cm

- Stage II
  - Material: E20, a_2=1.5 mm, b_2=2.7 mm, $\varepsilon_2 = 20$
  - E_{z2} = 158 MV/m
  - $\beta_{g2} = 1/\varepsilon = 0.05$
  - Stage II length L_2 = 80 cm
  - Net energy gain = 126 MeV

<u>Steps to accomplish these goals</u>

1. Completion of the new RF photocathode gun.
2. Implementation of high QE (CsTe) photocathode technology at the AWA. This has been demonstrated at a number of labs including A0 at FNAL and it is straightforward to upgrade the AWA photocathode preparation hardware to use it.
3. Splitting the laser beam:
   - Splitting laser beam in 4 (0.78 ns) apart (already available and tested).
   - Set up the existing laser beam splitter to 3.8 ns (currently 3.07ns) and split the beam into 8.
   - Put the two laser splitters in series and produce 32 laser pulses from each exit port.
   - The two laser outputs can be combined with one delayed to produce 64 pulses. This step is not required until the final experiment.

4. Construction of the Step-up transformer:
   - 7.8 GHz already fabricated and operational (both stage I and stage II).
   - Stage I of the 15.6 GHz tube is operational and stage II will be completed shortly.

5. Demonstration of high current pulse generation:
   - 5.1. 4 pulses (using the first laser splitter). Demonstrate 20 – 100 nC pulse generation.
   - 5.2. Demonstrate 7.8 GHz step up transformer using 40 – 50 nC beam with 4 pulses.
   - 5.3. Demonstrate high gradient acceleration in stage II of the 7.8 GHz tube (> 100 – 150 MV/m).
   - 5.4. Demonstrate 32 pulses with 20 – 50 nC charge in each pulse.
   - 5.5. Repeat 5.2 and 5.3 to accelerate beam to 47 MeV.

5.6. Extend the train to 64 pulses and then repeat 5.5 to achieve 95 MeV net energy gain in stage II.

6. Demonstration of high gradient in 15.6 GHz tube
   Reduce the charge to 20 nC/pulse. Repeat 5.6 but with structure II, achieving 126 MeV energy gain.

Conclusion

We have outlined an important experiment to be conducted after we have completed the RF gun upgrade. This experiment will use existing AWA resources already available except the high QE cathode. Based on the experience of other laboratories, however, we expect that the high QE technology can be incorporated without difficulty. The goal is to obtain 100 MeV energy gain in less a meter, a technologically interesting performance competitive with proposed high gradient conventional structures such as NLC. Based on our design, we believe the goal is reasonable and the result will have a positive impact on the accelerator community.

Meanwhile, we will also explore higher gradient wakefield devices using smaller acceleration lengths, limited by the AWA drive beam energy of 18 MeV. Based on our calculations, 100 – 200 MV/m gradients can be achieved in collinear structures.